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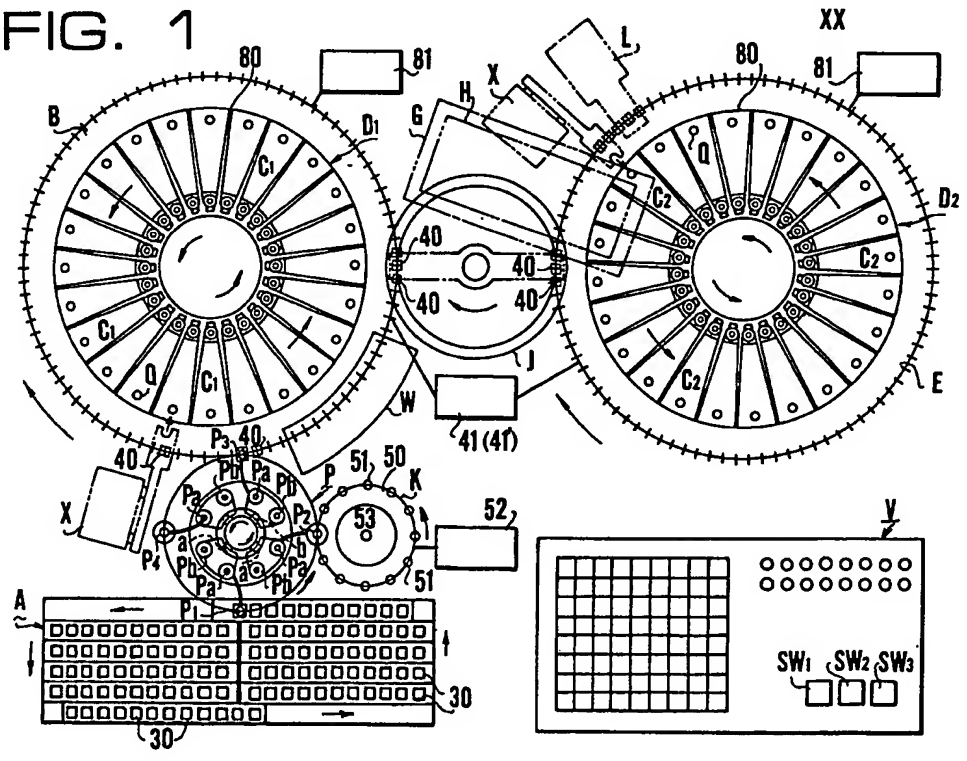
(54) Automatic analysis apparatus

(57) An automatic analytical apparatus in which a plurality of reaction tubes (40), are carried around a pair of spaced turrets (B,E). A reaction tube exchange means (J) automatically exchanges the reaction tubes held by one turret for those of the other turret at a predetermined position without stopping the rotation of the turrets. The turret (B) is associated with a rotatable holder (80) for reagent vessels (C). The reagent vessels may be cooled. Blood or other specimens are charged into the tubes at a pipette station (P_3), and reagent from a selected reagent vessel (C) is charged into the tubes at a station (X). The colour of the mixture in the individual tube is measured by optical means (G) while the tubes are carried around the turret (E) before being returned by the exchange means (J) to the turret (B) for cleaning in a washing station (W).

FIG. 1



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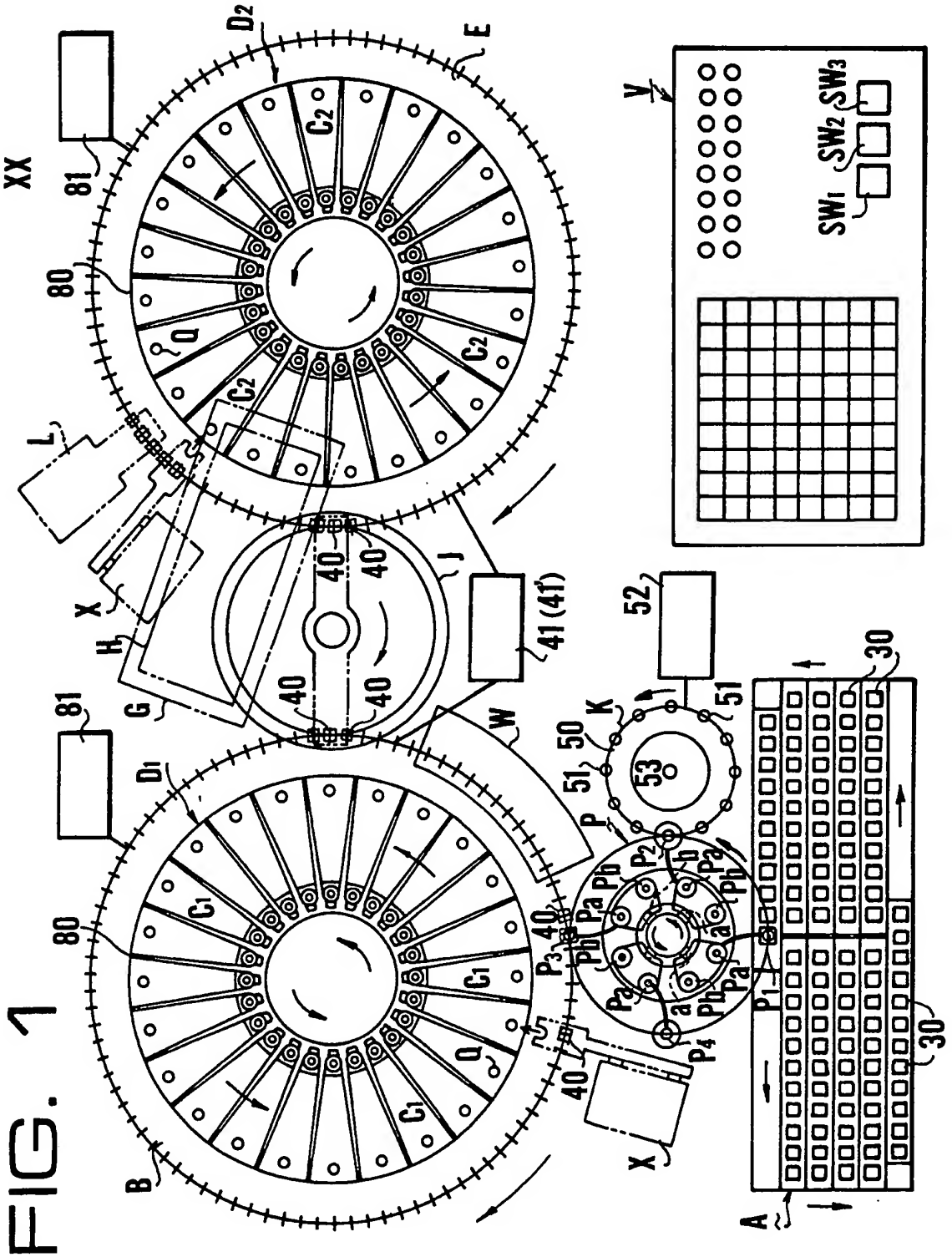

FIG. 1

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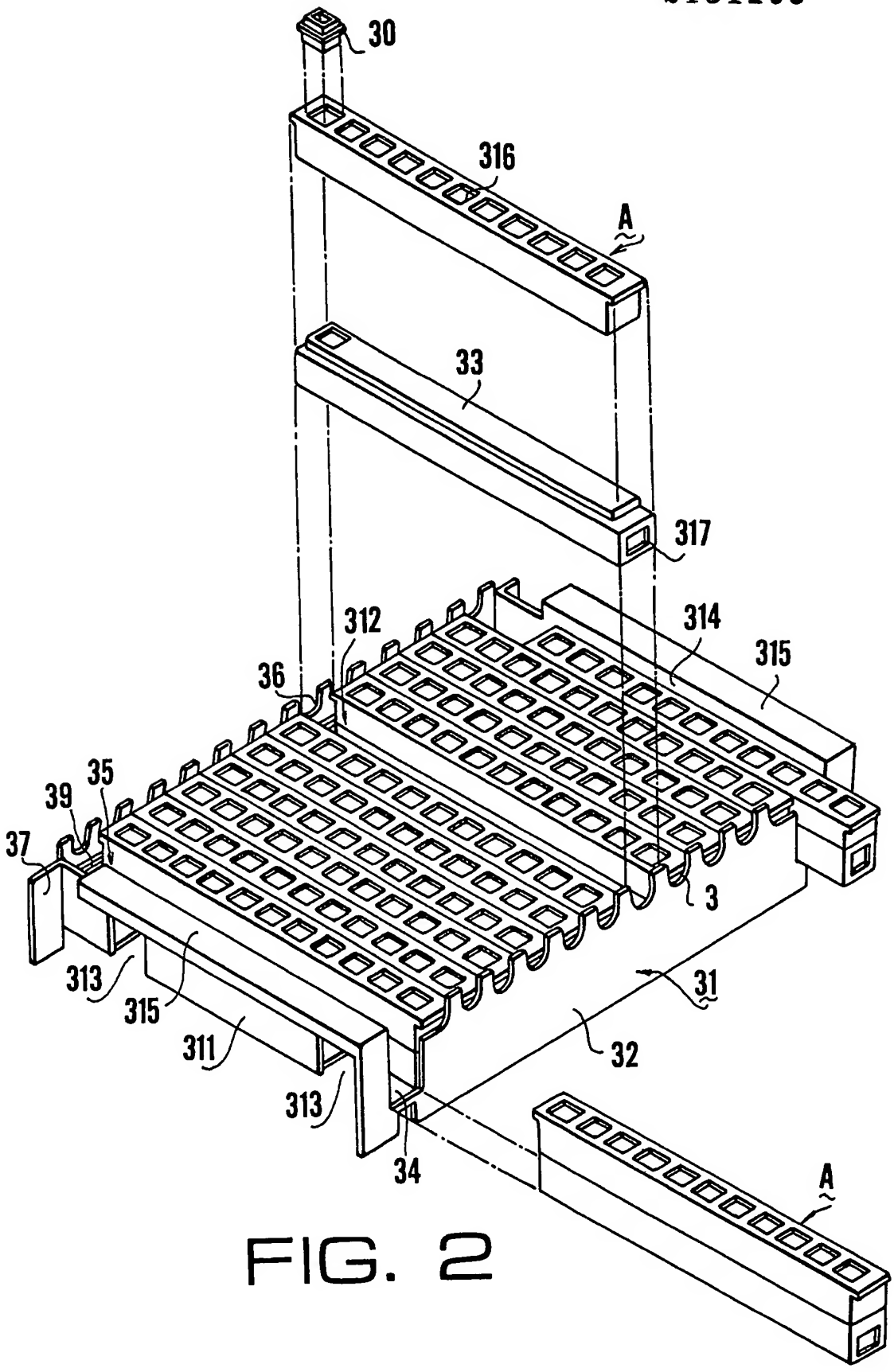

FIG. 2

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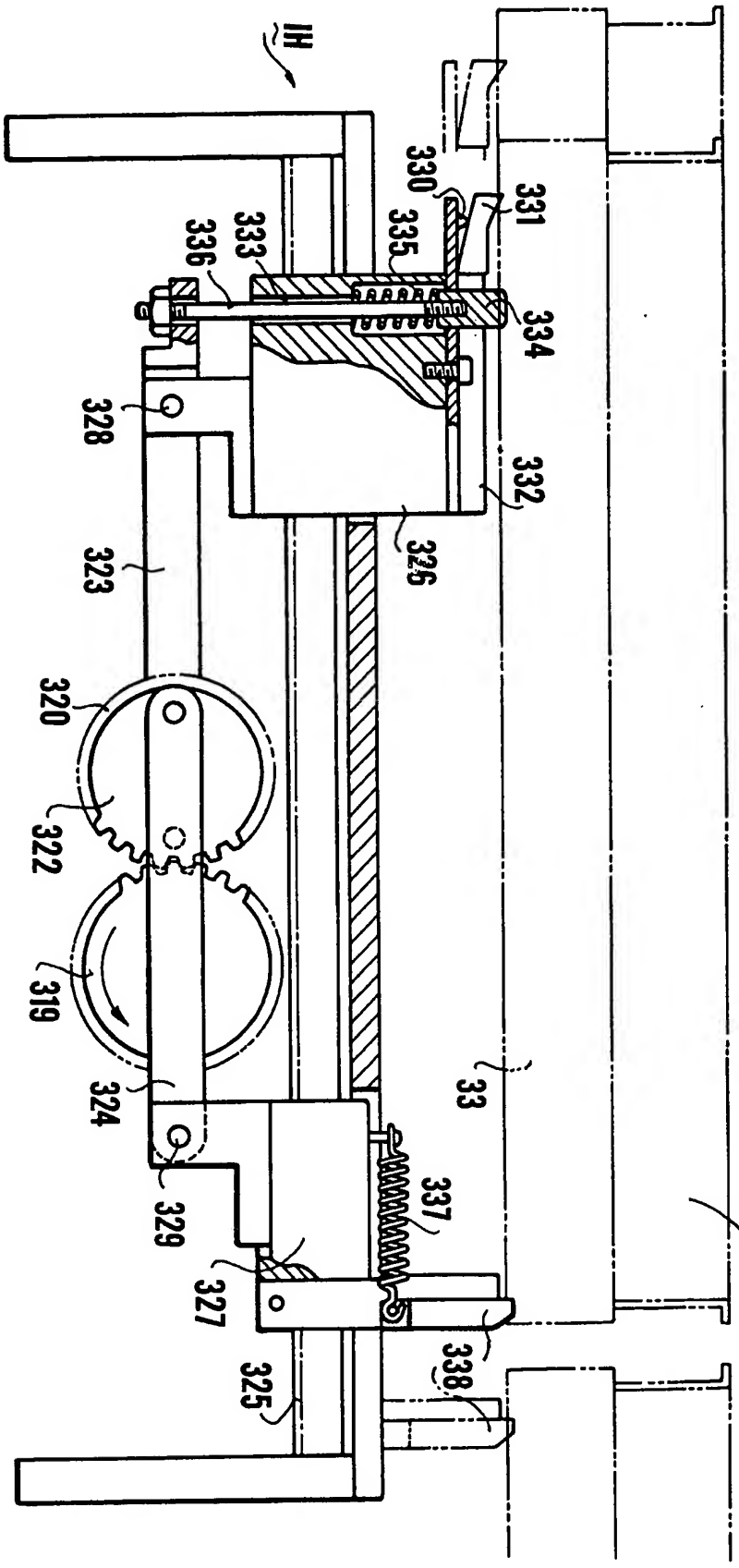

FIG. 3

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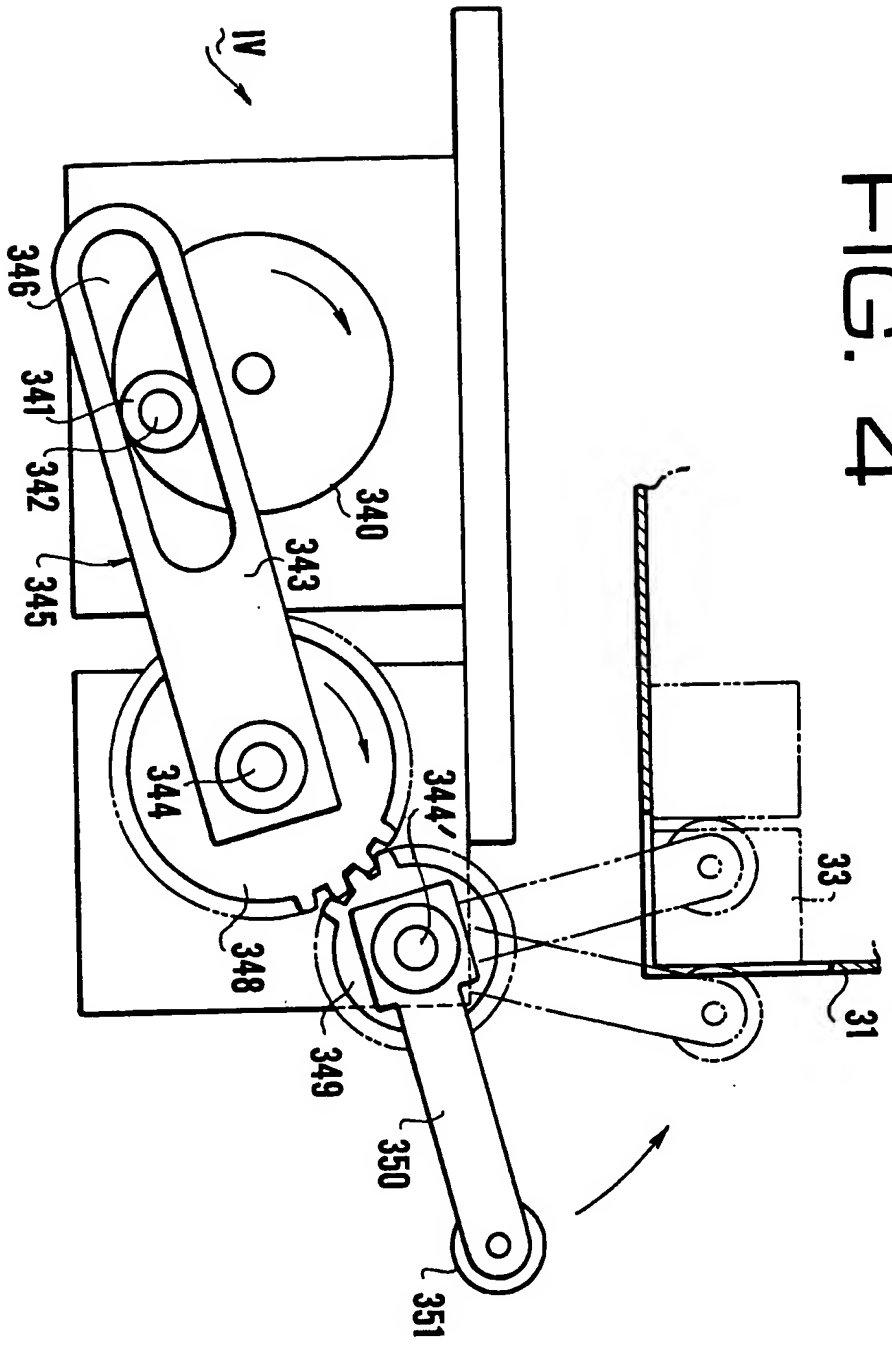

FIG. 4

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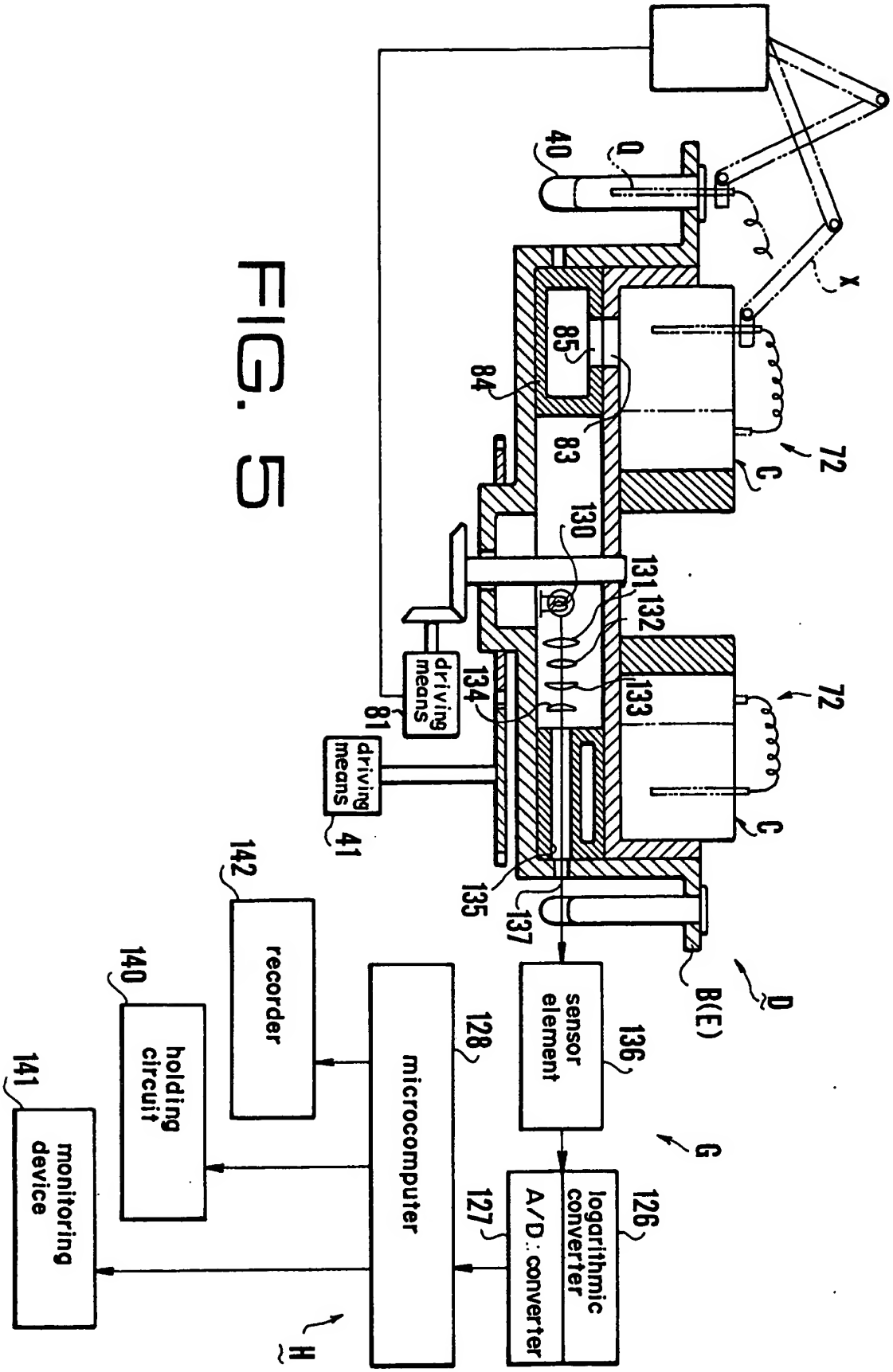

FIG. 5

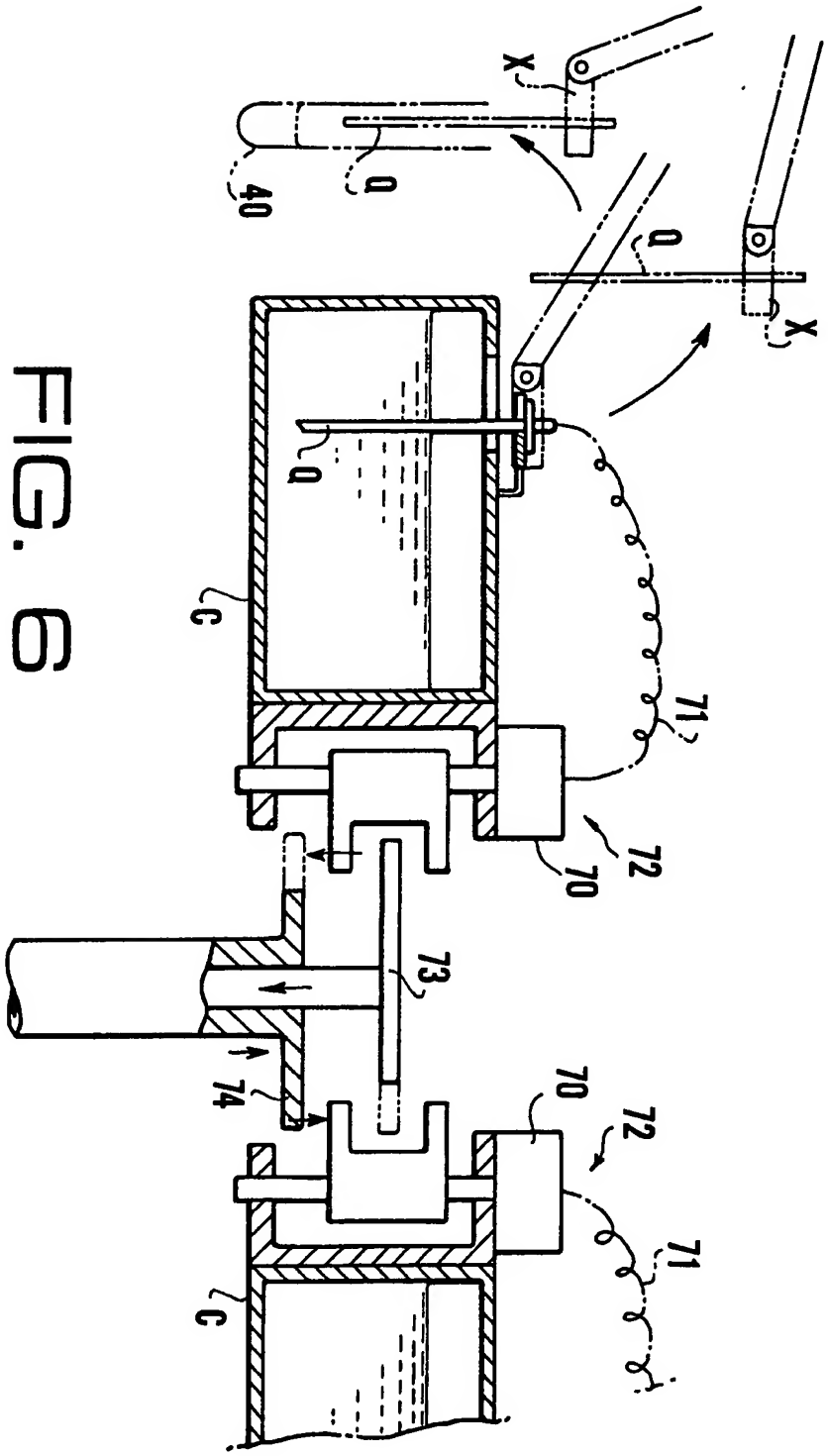

FIG. 6

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FIG. 7

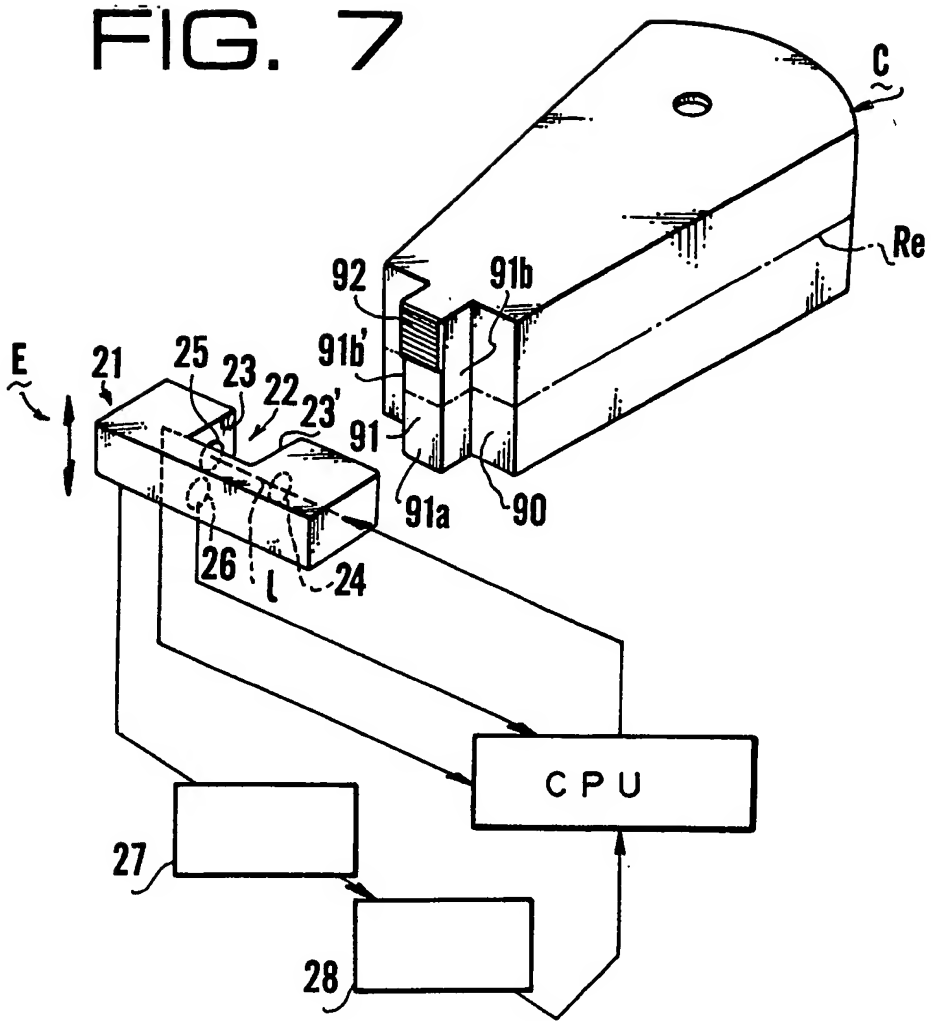
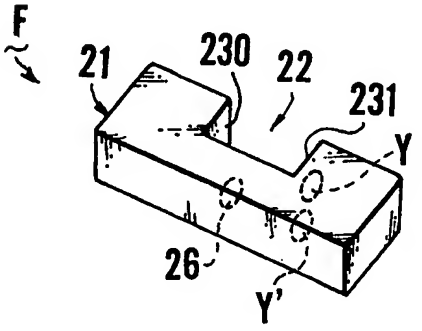


FIG. 8



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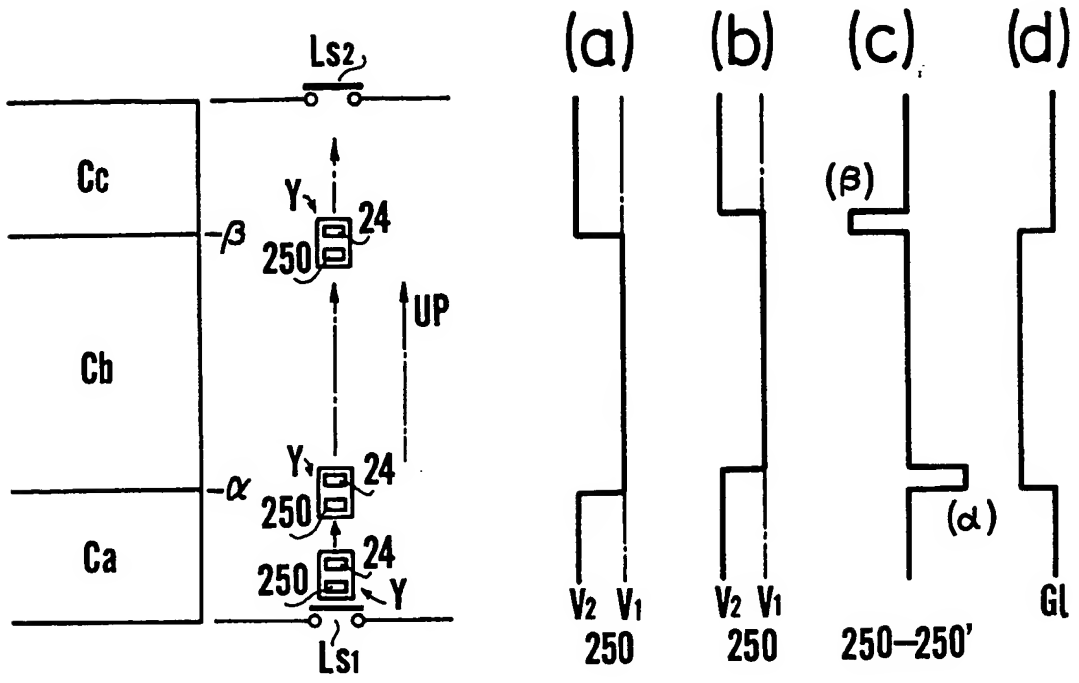

FIG. 9

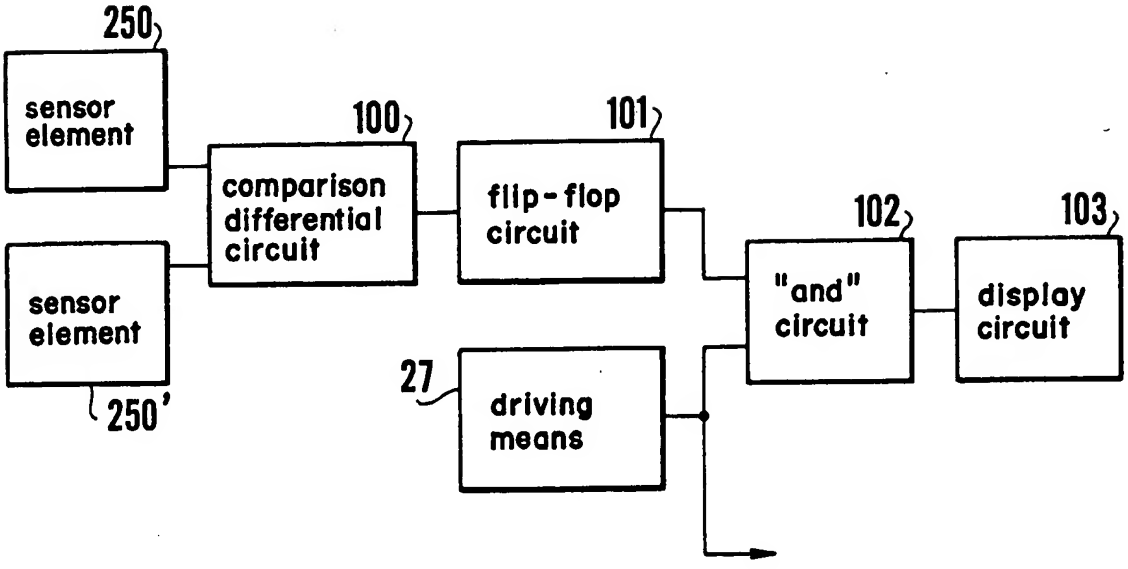

FIG.10

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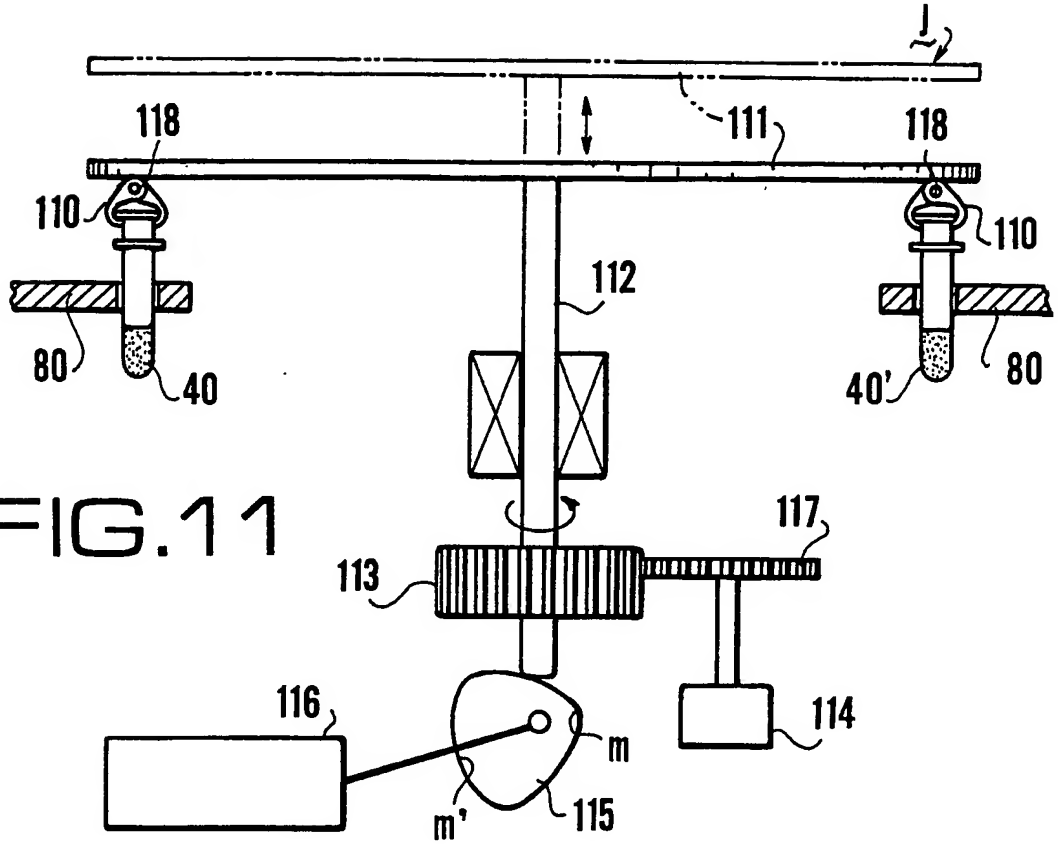
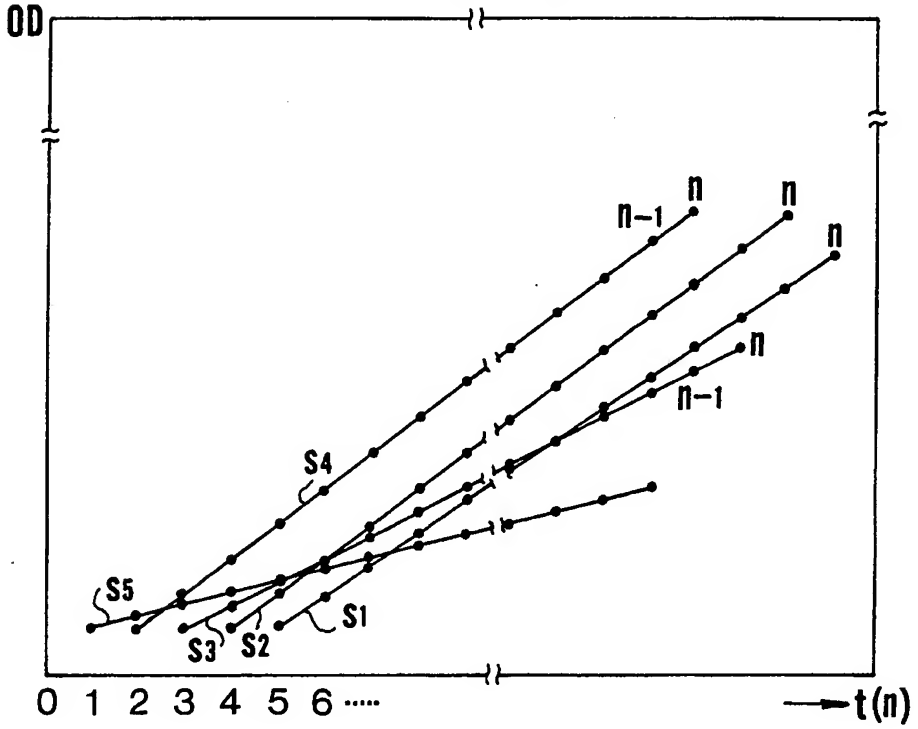


FIG.11

FIG.13



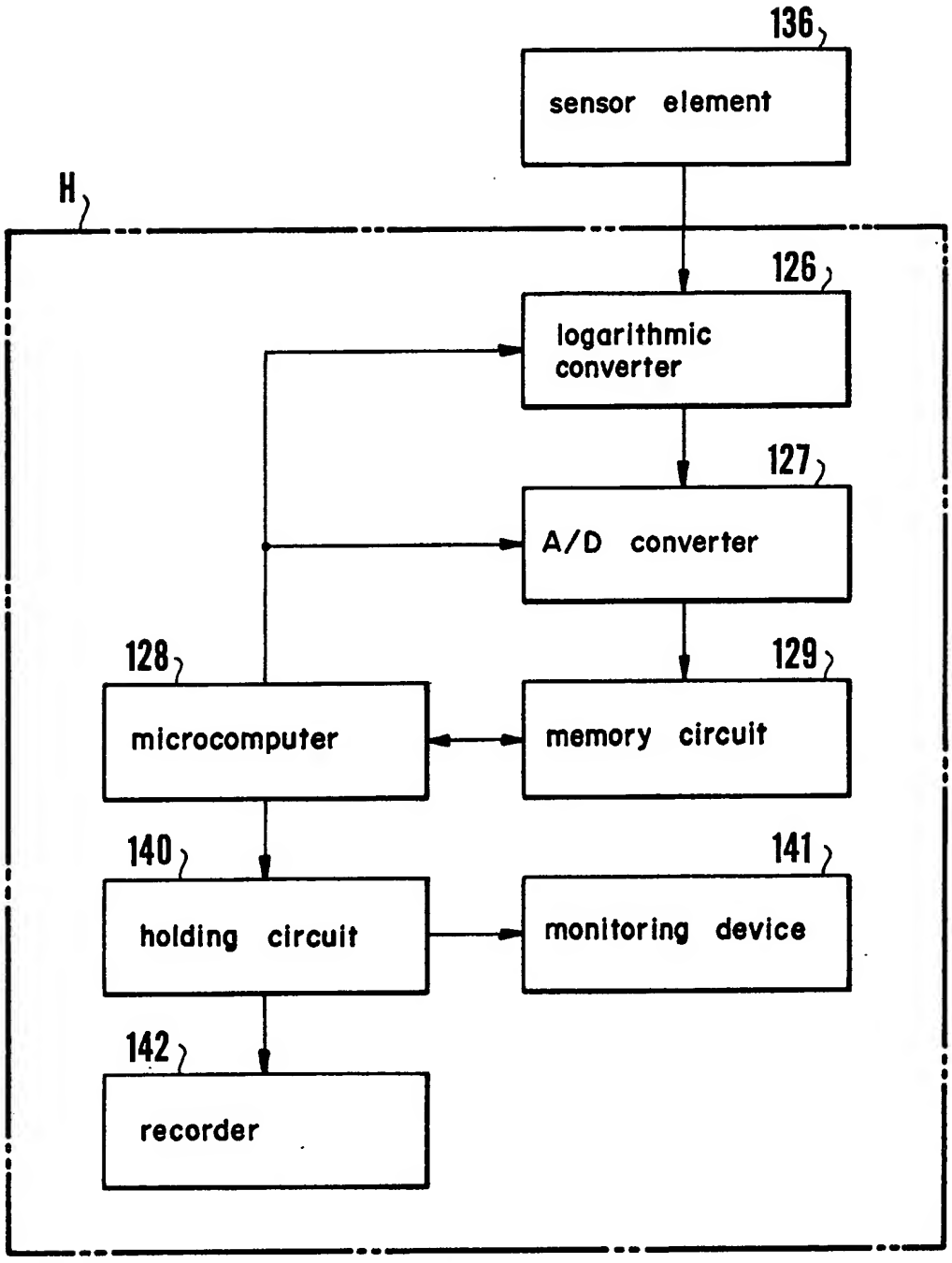

136
sensor element
H
126
logarithmic converter
127
A/D converter
128
microcomputer
129
memory circuit
140
holding circuit
141
monitoring device
142
recorder

FIG.12

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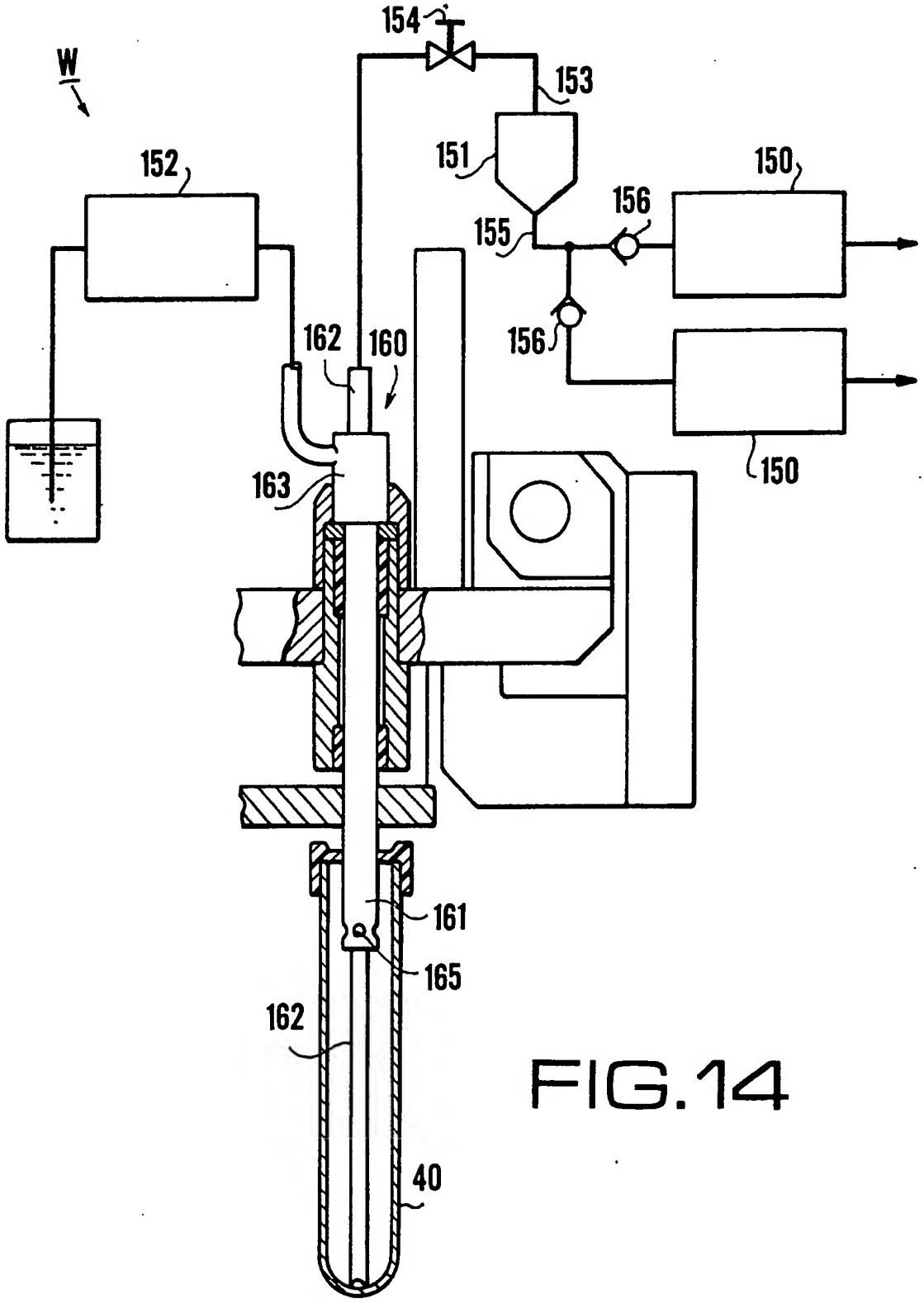

FIG.14

SPECIFICATION

Automatic analysis apparatus

This invention relates to medical precision measuring apparatus for analyzing a collected blood or other specimen in biochemistry or immunology, and particularly relates to an apparatus for analyzing substances present in a specimen by optically measuring the specific colour produced by the reaction of the specimen and a reagent which may be merely a diluent.

The apparatus disclosed in Japanese Patent Laid Open Application No. 56-168553 (Appln. No. 55-73210) is typical of the known art.

However, in prior apparatus of this type there are some defects as follows.

First, due to reaction tubes to be held in a reaction portion being suspended in one circular reaction table, the number of reaction tubes is limited according to the diameter of the table used. Therefore, in order to improve the capacity of the apparatus, and to increase the number of the reaction tubes, it is necessary to enlarged the diameter of the table. However, if the table is enlarged, the whole apparatus and the space which it occupies become unacceptably large. In addition, the use and manufacture of drive and stop controls for the reaction table become difficult.

Second, since such a series of operations as charging of and measuring a specimen and the cleaning of a reaction tube have to conducted in one resolution of the reaction table, a rotary speed of the reaction table is relatively slow to ensure that each of the operations are carried out properly and it takes a long time to treat one specimen.

Third, prior systems have the defect of making difficult the urgent measuring of a specimen in the case e.g. of an emergency operation.

The prior apparatus also does not satisfy the recent requirement of optical measurement using two reagents at a high speed and with high precision.

According to the invention, an automatic analytical apparatus for optically measuring a specific colour produced by a reaction of a specimen and a reagent comprises at least two parallel rotatable turrets for holding rings of reaction tubes containing specimens, a reagent vessel holder disposed coaxially with one of the turrets and holding a ring of reagent vessels, driving means for rotating the reagent vessel holder to bring a selected reagent vessel to a predetermined charging position, charging means for charging reagent from a reagent vessel at the charging position into an adjacent reaction tube, reaction tube exchange means for exchanging the reaction tubes held in the one turret for the reaction tubes held in the other turret, and an optical measuring means for optically measuring specimens in the reaction tubes when the reaction tubes are held in the other turret.

The other reaction tube holding turret may also be provided with a reagent vessel holder, vessels and driving means, and with the reagent charging means, if the specimens are to be treated with a second reagent prior to the optical measurement.

An example of an apparatus constructed in accordance with the invention is illustrated in the accompanying drawings, in which:-

Figure 1 is a schematic plan view;

Figure 2 is a perspective exploded view illustrating part of a sample cassette and a cassette tray of the apparatus;

Figure 3 is a vertical sectional view illustrating a crossfeed mechanism of the sample cassette shown in Figure 2;

Figure 4 is a vertical sectional view illustrating a longitudinal feed mechanism of the sample cassette shown in Figure 2;

Figure 5 is a partly vertical sectional view illustrating diagrammatically a feeder, a sampling device, an optical device and a digital processor;

Figure 6 is an enlarged diagrammatic view corresponding to part of Figure 5;

Figure 7 is a schematic perspective view illustrating a portion of a reagent vessel and a reading means;

Figure 8 is a perspective view illustrating a modification of the reading means;

Figure 9 is a diagrammatic view illustrating a working condition of the liquid level detector and an input condition of a corresponding electrical signal,

Figure 10 is a block view illustrating the liquid level detector;

Figure 11 is a schematic, front elevational view illustrating a reaction tube exchange device;

Figure 12 is a schematic block view illustrating a digital processor;

Figure 13 is a graph showing analyzed data displayed in a monitoring device; and.

Figure 14 is a partly vertical sectional view illustrating diagrammatically a cleaning device.

The illustrated biochemical automatic analysis apparatus has, as particularly shown in Figure 1, a plurality of sample cassettes A for ordinary specimens holding a plurality of cups 30, each of which may contain a predetermined amount of a specimen, such as blood. One sample cassette contains 10 cups for ordinary specimens and one cup for a comparative specimen. A sampler K holds specimens for emergencies. A pipette device P sucks up the ordinary specimens or the emergency specimens in a predetermined amount in a predetermined position and injects them into respective reaction tubes 40. A turret-like feeder B holds a ring of the reaction tubes 40. A reagent device D is disposed along the inner periphery of the feeder B in a coaxial relation with the feeder B had has, on a turret-like holder 80, a plurality of reagent bottles C, which are removably carried in the reagent device and which contain reagents appropriate to the measurements to be made. A reaction tube exchanged device J transfers the reaction tubes 40 charged with a predetermined amounts of specimens and predetermined amounts of reagent of predetermined types, from the feeder B to a measuring turret E. An optical device G measures the specific colour of the specimen contained in each reaction tube 40 which is held in the turret E for measurement. A digital processor H indicates and memorizes data determined by the optical

device G, and a cleaning device W cleans the reaction tubes after the above-described measuring operations have been finished.

A plurality of the sampe cassettes A for ordinary specimens are held in parallel relation in a cassette tray 31 as illustrated in Figure 2. This cassette tray 31 is formed in the shape of a rectangular box and at its front and back ends has a notch 34, 35 formed in the shape of a rectangle, so as to enable the introduction of the sample cassettes A for ordinary specimens mounted on a stand 33 as illustrated in Figure 2. In addition, there are provided in the cassette tray, at the top edge portions of the opposite side walls 32 and 37, a plurality of cut out portions each having generally the shape of a half circle corresponding to the width of the ordinary specimen sample cassette. Provided at the inner surfaces, and along the lower portions of the right and left side walls 32 and 37, are guide portions 39 for slidably guiding the sample cassettes A along the walls 32 and 37. Near an abutting portion of a front wall 311 and a bottom wall 312 are provided generally rectangular holes 313 and 313 through which arms of a longitudinal feeding means IV, for the sample cassettes A move. At upper portions of the front wall 311 and rear wall 314 are provided grip portions 315 and 315 for carrying the cassette tray 31. The cassette tray 31 is removably fitted in a sampler. In Figure 2, the sample cassette A is formed in a generally rectangular parallelopiped configuration and has the same length as the width of the side walls 32 and 37 of the cassette tray 31.

At an upper surface of the sample cassette A, there are eleven rectangular holes 316 in which the above described cups 30 are removably fitted. A stand 33 removably fits underneath the sample cassette A and as the same length as the sample cassette. The upper portion of the stand 33 is stepped so as to fit in the bottom of the sample cassette.

In addition, in the upper portion of the stand 33 there is provided a light transmitting hole for reading a code (not shown), and at the bottom of the stand there are provided hook holes 317 similar to the holes 316 of the sample cassette A. This hook hole 317 is used as a stop when the sample cassette A is crossfed.

Thus, when the ordinary specimen sample cassettes A are to be arranged in the cassette tray 31, specimens (serum) to be measured are first extracted and charged into each cup 30. Next, the sample cassettes A are put on the stands 33 to build up a two stage structure, and are then sequentially disposed in order in the cassette tray 31 to fill the interior of the cassette tray 31.

The cassette tray 31, so prepared with the ordinary specimen sample cassettes A, are push-in fitted to the sampler from a predetermined position at a touch.

When the analytical apparatus is switched on, the sample cassette A in the front row of the cassette tray is, together with the stand 33, first moved from the cutout portion 35 in the cross arrow direction (shown in Figure 1) intermittently, by a sample cassette cross feeding means IH (shown in Figure 3) so that each of the cups 30 successively reaches a position P_1 where a sample is sucked up as necessary. This cross-movement of the sample cassette A in the front row of the tray interlocks with a sample cassette disposed adjacent to the cassette A and pushes the adjacent sample cassette transversly at the same speed. When the sample cassette in the front row reaches the adjacent tray, a longitudinal feeding means IV (shown in Figure 5) is put into operation and extends an arm through the holes 313 to push the stand 33 in the last row of the cassette tray in a forward direction. At this time, all of the cassettes A in the cassette tray 31 slidably advance with their stands 33 by the width of one cassette. When the last sample cassette in the tray advances, the cross-feeding means IH is again put into operation and the same action as the above is repeated, whereby new sample cassettes are successively transferred to the cassette tray 31 through the cutout portion 34.

Referring to Figure 3, in the cross-feeding device IH comprising a part of a sample cassette feeding means, power from a motor is first transmitted to a gear 319 and hence to a gear 320. In the gear 320, a driving ring 322 is provided so as to interlock to the gear 320 and one end each of links 323 and 324 are mounted on the gear 320 and the driving ring 322 respectively on opposite sides of a supporting pillar. The other end of the link 323 is rotatably supported by a pin 328 at a lower portion of a first slider 326 which is slidably mounted on two parallel horizontal guides 325. The link 324 is rotatably supported by a pin 329 at a lower portion of a second slider 327 which is also slidably mounted on the horizontal guides 325. Both the first and second sliders are supported by the horizontal guides 325 extending into holes in central portions of their bodies.

On an end the first slider 326 is mounted a claw 331 which is urged upwards by a compression coil spring 330. The claw 331 has an upwardly inclined configuration. The claw is mounted on a claw holder 332. Further, the first slider 326 has a vertical throughhole 333 behind the claw 331. A shaft 336 penetrates the throughhole 333 and has at an upper end thereof a chip 334 urged upwards by a compression coil spring 335 and is connected at its lower end to an end of the link 323.

The second slider 327 has at an end thereof a claw 338 which is loaded by tension springs and formed with a part inclined in the same direction as that of the claw 331.

The claws 331 and 338 of the cross-feeding device IH, so formed, engage the holes 317 formed in the bottom of the stand 33 to enable the cross-feeding of the sample cassette A.

When the signal from the cross-feeding device is input to the control device (CPU), a motor drives to rotate the gears 319 and 320 through one revolution in the arrow direction as illustrated in Figure 3. While the gears 319 and 320 rotate 180°, the links 323 and 324 move to the opposite directions from each other and with this movement, the two sliders 326 and 327 also slide in the opposite directions from each other. In this case, the claw 331 engages a hole 317 formed in the bottom of the stand to allow the stand 33 to slides in the cross direction at intervals of one cup.

When the slider 326 returns, during the next half revolution of the gears, the claw 331 rides back downwardly under the stand by virtue of the weight of the stand 33 and the sample cassette A. When the gear 320 carries out the next revolution, the claw 331 fits in the next hole of the stand. The chip 334 projects into the holds 317 while the slider 326 moves forwardly, but when the slider 326 returns, the chip returns in a downwardly pulled state since the end of the link 323 connected to the shaft 336 pivots downwards about the pin 328.

A claw 338 fixed in the second slider 327 moves down by virtue of the operation of a tension spring 337 while the slider 327 slides backwardly. When the slider 327 is fully back, the claw 338 engages a hole 317 of the next stand 33 in the first row of the cassette tray, and when the slider 327 returns in position, it allows the stand 33 to slidably move one step. This return motion of the slider 327 synchronizes with the slider 326. Thus, the claw 331 of the first slider 326 and the claw 338 of the second slider 327 each moves the stand 33 and accordingly indexes the sample cassette A integral with the stand 33 in the cross direction step by step. At the time when this cross movement is terminated, a signal to the longitudinal feeding device IV as shown in Figure 4 is input.

Referring to Figure 4, in the longitudinal feed device IV, power from a motor provides a rotational motion to a crank 340. At one end of the periphery of the crank 340, a ball bearing 341 is provided around a bearing pin 342. This ball bearing 341 slides along an inner periphery of an elongate slot 346 which is provided at an end of a rocker arm 345. The rocker arm 345 has a base end 343 fixed to a shaft 344. The opposite end of the shaft 344 rotates depending on rotation of the bearing 341 and follows the up and down movement of the rocker arm 345. A gear 348 having a large diameter is fixed to this shaft 344 and meshes with a gear 349 having a small diameter which is fixed to a shaft 344' provided in parallel to the shaft 344. The shaft 344' has two feeding arms 350 fixed thereto and pivots depending on rotation of the bearing 341. A roller 351 at the tip of each arm 350 is rotatable and relieves contact resistance with the stand 33 disposed in the last row of the cassette tray 31. When a longitudinal feeding signal is input to the computer, a motor is driven and the crank 340 rotates in the arrow direction one full revolution. With this rotation, the bearing 341 rotates on the crack 340, sliding along the elongate slot 346 provided in the rocker arm 345, whereby the rocker arm 345 rocks with the bearing pin as a centre upwards and downwards. As the bearing 341 moves upwardly, the gear 348 rotates in the arrow direction illustrated in Figure 4, and the delivery arms 350 swivel upwardly depending on the rotation of the gear 349. In the swivelling process, the rollers 351 engage with the rear surface of the last stand 33 in the cassette tray 31 and causes the stand 33 to slide. The delivery arm 350 pushes the stand 33 continuously until the end of the rocker arm 345 reaches the maximum upward position. The gears 348 and 349 rotate in opposite directions from each other with the movement of the rocker arm 345, whereby the delivery arms 350 then swivel downwardly and return to their original position. The distance in which the stand 33 is slidably advanced by one swivel of the delivery arms 350 is predetermined. When the longitudinal delivery is finished, a signal is transmitted to the cross-feeding means and a similar operation as described before is repeated.

Thus, each of the ordinary specimen sample cassettes A mounted on the stands 33 is moved to a cross direction and in a longitudinal direction by the feeding device which is driven by the signal input in predetermined intervals whereupon the specimen (serum) is injected into each of the reaction tubes by a pipette P in a predetermined sucking position P_1.

In the illustrated arrangement, the ordinary specimen sample cassette A contains eleven similar cups 30 of specimen. Ten cups of the specimens, counting from the right, may contain human serum as the ordinary sample and the last cup contains a precision control substance such animal serum, or artificial serum.

Thus, it is preferred that the measurement is made in a combination of ten ordinary samples and one precision-control substance to obtain a more precisely measured value. However, it is not necessary to prepare such a precision-control substance in every specimen sample cassette. It may be sufficient in every other row or in every six rows of the sample cassettes.

Both of the ordinary samples and the control specimen are measured under the same conditions, that is, sucked by the pipette P in the sucking position, injected into the reaction tubes 40 and optically measured by the optical device G. In addition, the thus measured value is transmitted to a signal treating device H and automatically undergoes a data processing. The measured result of an ordinary sample is treated with consecutive numbering different from the result in the precision control specimen. Thus, since the number of the ordinary specimen sample is a multiple of number 10, the relationship of the data and the sample can be easily understood. The measured result of the precision control specimen is compared with a standard value of the control specimen in the digital processor H to detect automatically the accuracy of the control specimen at the measuring time in the apparatus, whereby the measured value of ten specimens of the ordinary samples are modified accordingly. Thus, the value resulting from the periodical measurement of the control substance, modifies the measured value of the ordinary sample until the next control specimen is measured.

Further, the reliability of the measured value overall may be obtained from the degree of scattering of the measured value of the control specimens by comparing the total of the measured values and a standard value of the control specimen.

It is not necessary to prepare the control sample in every sample cassette A as before described. If an empty cup, without containing the control specimen is set in the sample cassette, the position thereof is memorized previously in the digital processor H and quickly fed by a skip means (not shown) when the empty cup is transferred to the sample sucking

position, whereby a cup containing an ordinary specimen sample is quickly transferred to the sucking position saving time. The skip means is so constructed that the sample cassette cross-feeding means IH is actuated to feed the ordinary sample cassette continuously in two steps at once.

The sampler K is provided for urgent specimens, and removably abuts against the pipette P as illustrated in Figure 1. A specimen necessitating emergency analysis, for example, for data about an emergency operation, is contained in a plurality of vessels 51 which are held in a turret plate 50. The turret plate 50 rotates intermittently about a shaft 53 by a driving means 52. When the vessel 51 is transferred to a position P_2 for sucking the urgent sample in the pipette means P, the pipette P is actuated to suck up a predetermined amount of the sample. The operation in this case is controlled by the digital processor so that the driving sequence of the ordinary specimen sample cassette A is immediately stopped. After all of the urgent specimens are analyzed, the driving means of the ordinary specimen automatically starts to work. To facilitate the analysis of the urgent specimen, as shown in Figure 1 it is enough to switch over on the operation panel from a switch SW_1 for ordinary specimens to a switch SW_3 for urgent specimens. SW_2 as shown in Figure 1 is a stop switch.

The pipette means P comprises four pipettes held in a turret pipette holder and is controlled so as to intermittently move in a 90° arc by a motor (not shown) and a conventional cam mechanism or the like.

As the pipette holder moves, the pipettes suck up a predetermined amount of an ordinary specimen at position P_1 or suck up a predetermined amount of an urgent specimen at position P_2, inject the ordinary or urgent specimens into the reaction tubes 40 in a predetermined amount at position P_3. Then the pipette moves to position P_4 to clean up the pipettes and sequentially returns to position P_1 again.

In addition, each of the pipettes if fitted with a sucking pump Pa and a discharge pump Pb as shown in Figure 1, each of which engages cams for sucking and discharging the specimens under the control of the digital processor.

When the ordinary specimens are sucked and discharged, the sucking pump Pa and the cam *a* for each of the pipettes engage each other at the position P_1 as shown in a solid line in Figure 1, and the discharge pump Pb and the discharge cam for each of the pipettes engage each other at the position P_3. When the urgent specimens are sucked and discharged, the cam A for sucking the specimens moves so as to engage the sucking pump Pa at the position P2 and a cam *b* is arranged to engage the discharge pump Pb at the position P_3. When the sucking and discharge of the urgent specimens are finished, the sucking cam automatically returns to the sucking position P_1 for the ordinary specimens from the position P_2 by an instruction signal from the digital processor H.

Thus, the reaction tubes 40 filled with the ordinary or urgent specimens are held in the feeding means In the shape of a turret which is intermittently rotated through driving means 41, such as a Geneva gear, and transferred to a position for charging a reagent, where a first reagent is charged into the reaction tubes 40 by the first reagent means D_1.

Referring to Figures 5 and 6, the first reagent device D comprises reagent bottles C being made of a light-transmitting material at least at the bottom thereof, and mounted on a rotatable holder having a shape of a turret made of a light-transmitting materal. A driving means 81 rotates the turret to transfer a selected reagent bottle C to the reagent charged position at a high speed, and a reagent pipette Q then picks up the reagent from the reagent bottle C and charges it to the reaction tube 40. Particularly, the turret holder 80 is disposed radially inwardly of the feeding means B in coaxial relation thereto. The ring of radially extending reagent bottles C are removably mounted and in the reagent bottles C various reagents are contained according to the required analysis. Thus, the turret holder 80 is controlled by the driving means 81 so as to rotatably transfer the reagents necessary for analysis.

The reagent bottles C described above may comprise a reagent bottle containing a reagent suitable for room temperature storage, for example, T.P., Z.T.T. or the like, and a reagent bottle containing a reagent necessitating cool storage, for example GOT, GPT or the like. The reagent bottle for cool storage is disposed in a selected place on the turret holder 80. At this place a plurality of holes 83 are provided, whilse elsewhere no hole is provided.

On a lower portion of the turret holder 80, a duct 84 made of a light-transmitting material is provided in coaxial relation with the turret holder 80. On an upper surface of the duct 84, a cool air supply hole 85 communicating with the hole 83 is provided at predetermined places. The duct 84 is fixed and does not rotate with the turret holder 80.

A cooling medium flowing in the duct 84 flows from the air supply hole 85 through the hole 83 to the bottom of the reagent bottle for cool storage to cool and preserve the reagent in the cooling reagent bottle. The reagent bottle for room temperature storage is not cooled.

When the reagent bottle C containing a first reagent is transferred at a high speed to the position where the reagent is charged in the manner as described herein, an epansible reagent pipette Q mounted on each reagent bottle C is pulled out and led to the position of the reagent tube 40 by a holding means X, thereby to charge the first reagent into the reaction tube 40 in a predetermined amount.

Each reagent bottle C is provided, as illustrated in Figure 6, with a pump 70, an expansible pipette tube 71 connected to the pump 70, and a reagent pipette Q connected to the end of the pipette tube 71. The pump 70 engages a projecting portion of a rotating cam 73 and descends to suck up the first reagent. Then, the cam 73 releases its engagement with the pump 70 and returns to the neutral position. Thereafter, the arm of the holding means X extends to grip the reagent pipette, pulls the reagent pipette Q outwardly from the reagent bottle C, and leads it to the reaction tube 40, whereafter the first reagent is charged into the reaction tube 40 by the reagent

pipette Q in a predetermined amount upon ascension of a second cam 74. At this time, the pipette tube 71 is free to be led to a predetermined position since it is expansible. Thereafter, the holding means X releases the reagent pipette Q, while the reagent pipette returns to the original position by means such as a spring or the like. Then, the pump 70 may again engages the cam 73 and the same operation explained above is repeated.

As illustrated in Figure 7, the reaction bottle C is of a generally rectangular configuration with an arcuate side and has a rectangular projection wall portion 91 enclosing a zone which communicates with the interior of the reaction bottle C. The projecting portion is made of an excellent light-transmitting material. In a front surface of the projecting portion at an upper end portion 91a, above the level of liquid in the bottle, there is a discriminating body on which data representing the kind, date of manufacture etc. of the reagent contained in the bottle is coded e.g. as a bar code or binary code.

A detector as illustrated at E in Figure 7 is disposed radially within the reagent means D as illustrated in Figure 1 and is adapted not to participate in the rotation of the reagent device. The detector E comprises a detector bracket 21 which may be lifted along the projecting portion 91 of the reagent bottle C at a predetermined speed, a light source 24 and a photosensitive element 25 being disposed in opposite side surfaces 23 and 23 of a recess 22 formed in the detector bracket 21. A known type of optical reading element 26 is disposed in the bottom portion of the recess 22, and a potentiometer 28 senses the extent of the lifting movement of the bracket 21 by detecting a rotary angle of a driving means 27 which drives the bracket 21.

When another reagent bottle C is transferred to and stopped at a reagent charging position, the detector E simultaneously starts to rise upwardly and detects a characteristic of the reagent and/or the level of the fluid reagent in the reagent bottle C, and the detected data is input to a control means (CPU).

More particularly, such detection may be conducted as follows. When the reaction bottle C to be detected reaches a predetermined position and stops, first the detector bracket 21 starts to rise upwardly while embracing the projecting portion 91. Then a light having a specific wavelength, from the source 24 is simultaneously incident on the side wall 91b of the projecting portion 91. The applied light is transmitted through the walls from one side wall 91b to the other side wall 91b' and then received by the photosensitive element 25. The received light is converted to a voltage and input to the control means (CPU) from the photosensitive element 25.

When the light is transmitted through the reagent Re in the reagent bottle C, the intensity of the light received by the element 25 is subject to absorption in the reagent Re, but when the light is transmitted through gas above the reagent level in the reagent vessel C, the intensity of the light received by the element 25 is greater since absorption does not occur. The time of change in the transmitted light intensity, i.e. the variation in voltage is compared with a rotary angle of the driving means 27 detected by the potentiometer 28. As a result a height of liquid in the vessel and the amount of residual liquid reagent is computed by the control means (CPU), and the data is indicated in a display.

The data relating to the reagent in the reagent bottle C is differentiated optically from the distinguishing display 92 by means of a conventional optical reading element 26 and input to the control means. The reagent device D is controlled by the driving means 81, 81 in a manner based in the obtained data.

Referring to Figure 8, a modification F of the detector E comprises a detector bracket 21 having a pair of detectors Y and Y' each including a light source and a photosensitive element and being disposed above one another at one side 231 of a recess 22, and a conventional optical reading means 26 in the other side of the recess.

The light source 24 and the element 250 in Y and Y' are vertically spaced and the light, such as ultraviolet light, which is irradiated by the source 24 and reflected by the side surface of the projecting portion 91b, may be received by the corresponding photosensitive element 250.

The reason why the detectors Y and Y' are spaced is to protect a liquid level detection from a variability of light intensity related voltage which is caused by a concave or convex flaw, or other discontinuity, in the reflecting surface of the bottle C or a variability of voltage which is caused by an inaccuracy between the distances of the reflecting surface of the bottle and the sensor element. In order to increase liquid level detecting precision, a plurality of the detecting bodies may be provided. Even one body is sufficient. Thus, the light irradiated from the source 24 and reflected by the reflecting portion of the bottle (the side wall 91b in Figure 7) is received by the corresponding sensor element 250 in the state as illustrated in Figure 9 and converted to the corresponding voltage. (In Figure 9, only one detecting body is illustrated).

Referring to Figure 9, as the photosensitive elements 250 move from a lower position Ca of the bottle to a reagent layer Cb, voltage signal levels as shown (a) and (b) of the corresponding sensor elements 250 move from a level V_2 to a level V_1 at a threshold line α, and thereafter as the sensor elements 250 move from a reagent layer Cb to an air layer Cc, voltage signal levels of the sensor elements 250 move from a level V_1, to a level V_2 at a threshold β. In this case, signal outputs from the sensor elements 250 are input to a comparison differential circuit 100 as illustrated in Figure 10 as a difference in time between the distances of the sensor elements 250, since they are spaced from each other, whereby a direction of the differential voltage between the sensors is discriminated. Then the signal output is input to an "and" circuit 102 from a flip-flop circuit 101. The signal from the driving means 27, for example a pulse signal in case of a pulse motor, is input to the control means at the "and" circuit to carry out necessary operation, and is input to a display circuit 103. In Figure 9, Ls2 denotes a lower limiting circuit and Ls1 is an upper limiting circuit.

The liquid detection is made by a comparison operation of a gate time signal G1 and a pulse signal of the driving means 27. Further, the liquid detection may be made by a comparison operation of data obtained from detecting a rotary angle of the driving means by a potentiometer, and data relating to the voltage of the elements 250.

Thus, each reaction tube 40 in which the specimen and the first reagent are charged is intermittently indexed until it reaches a predetermined position where the reaction tube 40 is transferred to a measuring turret E through a reaction tube exchange means J.

The reaction tube exchange means J illustrated in Figures 1 and 11 lifts a reaction tube 40 held in the feeding means B and the reaction tube 40' held in the measuring turret E at its opposite end, and rotates them through a 180° arc, thus exchanging the reaction tube 40 for the reaction tube 40', so that the reaction tube 40 is placed in the position where the reaction tube 40' was held and the reaction tube 40' is placed in the position where the reaction tube 40 was held.

More particularly, the reaction tube exchange means J comprises a supporting arm 111 having picking arms 110 at both ends thereof, a lifting rod 112 being fixed in the centre of the supporting arm 111. A gear 113 is fixed on the lifting rod near the lower end thereof, and a driving means 114 causes the lifting rod 112 to rotate in a predetermined direction via a gear 117 in mesh with the gear 113. An eccentric cam 115 abutting a lower end of the lifting rod and a motor 116 rotates the eccentric cam 115.

Thus, the lifting arm 112 may be raised and lowered between a lowest position corresponding to a shortest radius portion of the eccentric cam 115, and a highest position corresponding to a longest radius portion of the eccentric cam 115. In the highest position the driving means 114 is operated while the supporting arm 111 rotates through 180°. The picking arms 110 are supported by a pin and diverge and then converge at the ends thereof. When the lifting rod 112 is positioned in the lowest position, the picking arms clamp the reaction tubes 40 and 40' through a conventional timing mechanism and after being raised, rotated through 180° and lowered, release the clamping.

Since the exchange of the reaction tubes 40 and 40' is executed during the transfer of the reaction tubes, without stopping the apparatus, the measuring time is shortened. In addition, since the structure of the apparatus is simple, failure is infrequent and the maintenance is easy.

In the illustrated construction, the lifting control of the lifting rod is made by the eccentric cam 115 but another form of actuator could equally well be used.

A reaction tube 40, after having been transferred to the measuring turret E, is further transferred by rotation of the turret to a position in which a second reagent is charged into the tube.

Since the structure and operation of the second reagent device D_2 are similar to those of the first reagent device D, duplicate explanation is omitted here.

If in any measuring technique it is not necessary to charge the second reagent, the signal for second charging is automatically cancelled.

A reaction tube 40, thus charged or not with the second reagent, is transferred to a stirring position. The stirring is made by a conventional supersonic vibration means L during the exchanging the reaction tubes and in such a manner as not to disturb the rotation of the measuring turret E.

The optical device G disposed in the measuring turret E comprises a light beam from a light source lamp 130, which is collimated by lenses 131, 132, 133 and 134 and passes through a cylindrical portion 135, before being transmitted through the reaction tube 40 from a hole provided on the measuring turret E, and being incident on a sensor element 136.

More specifically, the hole 137 is formed in a vertical wall portion of the measuring turret E and in an orthogonal direction to the turret axis. The measuring turret E rotates at least 360° plus one pitch (the next reaction tube-held position), during one intermittent motion of exchange of the reaction tubes by the exchange means. The measurement by the optical measuring device is thus applied several times or many times to one reaction tube held by the measuring turret E, whereby measurement precision is improved and the time related change in reaction can be easily measured.

Thus, the data analyzed by the specific colour measurement in the optical device G is input to a digital processor H as illustrated in Figure 12. The digital processor H comprises a logarithmic converter 126, an A/D converter 127 converting the analysis data input to the logarithmic converter 126 to a digital signal, a microcomputer 128 including a memory circuit 129 which memorizes the digital signal input to the A/D converter 127, a holding circuit 140 holding the memorized and analyzed data of every one specimen measured, a monitoring device indicating the analyzed data of every one measured specimen after measuring a time course of the same specimen, and a recorder 142.

The specific colour measurement of the blood specimen held by the measuring turret E is optically made plural times (n times) while the reaction tube 40 is transferred from the measuring position to the cleaning position, and the analyzed data of every one optical measurement on one specimen is transferred to the memory circuit. When the optical measurement is made plural times (n times) a time related change in the reaction is operated and transferred to the holding circuit 140 for every one specimen and the data necessary for time course display is held for every one specimen. The data held in the holding circuit 140 is displayed as a time course graph in the monitoring device as illustrated in Figure 13.

The time course graph indicates the analyzed data over plural times (n times) for plural specimens s1, s2, s3, ...sn.

In Figure 13, five specimens are indicated in order for a display area of the monitoring device 141. If one specimen is optically measured for 4 seconds n times, the time course graph for the specimen is displayed for 20 seconds. Thus, after the time course

of the specimen s1 goes out, a time course of the sixth specimen s6 is displayed in the monitoring device 141 and successively a time course of sn is displayed.

Therefore, by monitoring a time course of the same specimen, the progress state of reaction of a specimen and the reagent used therewith and a theoretical reaction state can be compared. Further, a record of the time course can be printed by the memory 142, if it is necessary.

The measurement of a specimen explained herein as one embodiment is made by a specific colour measurement using an optical means but may be made by a voltage measurement.

The reaction tube 40, after measurement is transferred to and arranged in the feeder B by the reaction tube exchange means J and further transferrred to the cleaning means W by the feeder B as described before.

The cleaning means W comprises, as illustrated in Figure 14, two vacuum pumps 150 sucking and discharging a cleaning treating water, a vacuum tank 151 connected to the vacuum pump 150, a cleaning nozzle 160 connected to the vacuum tank 151 and dropping downwardly into a tube 40 at the time of cleaning, a water supply pump 152 hydraulically supplying cleaning water to the cleaning nozzle 160, an electromagnetic valve 154 disposed in a water pipe 153 connected to a drain side of the cleaning nozzle 160 and the vacuum tank 160, and check valves 156 disposed in water pipes 155 connected to the vaccum pumps 150 and the vacuum tank 151.

The cleaning nozzle 160 comprises a cleaning water charging pipe 161 having a large diameter and a short length, and a cleaning water drain pipe 162 disposed in the cleaning water charging pipe 161 and having a narrow diameter and long length. The cleaning water drain pipe 162 is held by a seal material disposed in the opposite end portion of the cleaning water charging pipe 161, in coaxial relation with the cleaning water charging pipe 161. Further in the cleaning water charging pipe 161, at the lower end, a plurality of holes 165 are disposed radially in order to dispense cleaning water toward the inner wall of the reaction tube. The seal placed on the top end of the cleaning water charging pipe 161 has a connecting nozzle which dispenses cleaning water from the water pump 152 to a passage defined by the inner wall of the cleaning water charging pipe 161 and the outer wall of the cleaning water discharging pipe 162.

The cleaning means W thus functions as follows:

First, when the reaction tube 40, after measurement, is transferred to a position just under the cleaning device, the cleaning nozzle 160 is lowered by a lifting means (not shown) and set to start the cleaning.

Next, cleaning water is hydraulically dispensed into the cleaning water charging pipe 161, then is radially sprayed toward the inner periphery wall of the reaction tube 40 through the holes 165 and flows downwardly to the inner bottom portion of the reaction tube 40 for cleaning out the reactant adhered on the inner periphery wall or a suspended matter in air. Simultaneously with the operation of the cleaning water, the vacuum pump for discharging water starts to work so that cleaning water is instantaneously sucked in the cleaning water discharging pipe 162 with the residue of the reaction and transferred into the vacuum tank 151 and discharged. The cleaning operation may be repeated several times. After the cleaning treatment is finished, the reaction tube 40 is transferred into position to be used again.

It is possible to incorporate an ultrasonic cleaning treatment step in the multiple stage cleaning treatment course by the cleaning nozzle 160 to clean the reaction tube more completely.

CLAIMS

1. An automatic analytical apparatus for optically measuring a specific colour produced by a reaction of a specimen and a reagent, the apparatus comprising at least two parallel rotatable turrets for holding rings of reaction tubes containing specimens, a reagent vessel holder disposed coaxially with one of the turrets and holding a ring reagent vessels, driving means for rotating the reagent vessel holder to bring a selected reagent vessel to a predetermined charging position, charging means for charging reagent from a reagent vessel at the charging position into an adjacent reaction tube, reaction tube exchange means for exchanging the reaction tubes held in the one turret for the reaction tubes held in the other turret, and an optical measuring means for optically measuring specimens in the reaction tubes when the reaction tubes are held in the other turret.

2. An apparatus according to claim 1, which includes a plurality of pipettes in a turret pipette holder which is intermittently rotated to move the pipettes from a specimen sucking position to a pipette cleaning position through a specimen charging position at which a specimen is charged into a respective reaction tube.

3. An apparatus according to claim 2, wherein there are two specimen sucking positions corresponding to routine and emergency measurements respectively, and each pipette is arranged to suck a specimen at a selected one of these positions.

4. An apparatus according to any one of the preceding claims, wherein each reagent vessel has a projecting wall portion formed at one part of the vessel and enclosing a zone which communicates with the interior of the vessel.

5. An apparatus according to claim 4, wherein the reagent vessel holder has, adjacent to its centre, detecting means which is movable up and down the projecting wall portion of a respective reagent vessel and is arranged to sense the level of other data of a liquid in the vessel.

6. An apparatus according to claim 4, or claim 5, wherein the projecting wall portion carries indicia relevent to the reagent in the respective vessel.

7. An apparatus according to claim 6, wherein the driving means for rotating the reagent vessel holder responds to reading means which reads the indicia.

8. An apparatus according to any one of the preceding claims, wherein the ring of reagent ves-

sels is radially within the respective ring of reaction tubes.

9. An apparatus according to any one of the preceding claims, wherein the reaction tube exchange means is positioned between the reaction tube holding turrets and includes an arm with means at each end for gripping and lifting a reaction tube one from each turret, and means for rotating the arm through 180°.

10. An optical analytical apparatus substantially as described with reference to the accompanying drawings.

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